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UCRL-TM-205526-REV-1

Atmospheric Modeling Product-Related Terms and Acronyms

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August 9, 2004

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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Introduction

Atmospheric modeling programs at Lawrence Livermore National Laboratory (e.g. those utilized by the National Atmospheric Release Advisory Center, NARAC, and the Inter-agency Modeling and Atmospheric Assessment Center, IMAAC) provide products (maps) of the potential effects from nuclear, radiological, chemical, and biological atmospheric releases. These products typically employ a variety of specific terms and acronyms that may not be familiar to all the users of these products.

This document defines several of these terms and lists many of the acronyms which our users may encounter. There are three sections to this document: (1) the Definition of Terms which briefly discusses some basic descriptions of Radiation Dose, Protective Action Guides, Public Exposure Limits, and Derived Response Levels (among other items) as they relate to our model products, (2) a list of acronyms used in the Definition of Terms and on our products and reports, and (3) a short list of references used in the Definition of Terms.

KTF – September 18, 2003

Definition of Terms

Activity: See *Radioactivity*.

Acute: Refers to effects that occur over a relatively short time period, typically hours to weeks. Primarily used to distinguish relatively severe, near-term (acute) health effects (such as illness, incapacitation, or death) from longer-term (*chronic*) health effects (such as the future development of cancer or genetic disorders) that may develop as a result of exposure to hazardous materials.

Acute Exposure Guideline Levels (AEGLs): One of the three sets of standard chemical air concentration levels used to estimate the health and safety effects from industrial chemical or chemical warfare agent releases. (*TEELs* and *ERPGs* are the other two sets.) AEGLs are developed by the National Advisory Committee (which is chaired by the Environmental Protection Agency), and, if available for the chemical of interest, are used in preference to the *ERPG* or *TEEL* values. There are up to three AEGL concentrations (labeled as AEGL 1, AEGL 2, and AEGL 3) that reflect increasingly severe health effects with increasing concentration. Each of these concentrations is published for a particular exposure period (typically 10-minute, 30-minute, 1-hour, 4-hour, and 8-hour). The 10-minute exposure limits are used as the default values for NARAC products.

Atmospheric Release Advisory Capability (ARAC): A program at Lawrence Livermore National Laboratory (LLNL) that supports emergency response for facilities and agencies of the U.S. Departments of Energy and Defense. ARAC uses atmospheric transport and diffusion models to estimate the impacts on human health and safety resulting from atmospheric releases of radiological materials or other hazardous substances.

Chronic: Refers to effects that occur over a relatively long time period, typically months to years. Primarily used to distinguish longer-term (chronic) health effects (such as the future development of cancer or genetic disorders) from relatively severe, near-term (*acute*) health effects (such as illness, incapacitation, or death) that may develop as a result from exposure to hazardous materials.

Contamination: The presence of hazardous material in previously unaffected areas at levels that may be harmful to public health and the environment.

Coordinated Universal Time (UTC): Specifies that the associated time is equivalent to the mean solar time at the prime meridian (0 degrees longitude). Formally known as Greenwich Mean Time or GMT. Also referred to as Z or Zulu time. To convert to the common time zones in the conterminous United States:

To Convert To This Time Zone	Subtract This Number of Hours from UTC Time
Eastern Standard Time	5
Eastern Daylight Time	4
Central Standard Time	6

Central Daylight Time	5
Mountain Standard Time	7
Mountain Daylight Time	6
Pacific Standard Time	8
Pacific Daylight Time	7

Derived Intervention Level (DIL): Derived Intervention Levels (DILs), developed by the U.S. Food and Drug Administration (FDA 1998), specify the concentration of radioactive materials in food that, if ingested in a manner consistent with a set of assumptions used by the FDA, will produce a *Committed Dose Equivalent* (see *Radiation Dose*) to an individual that exceeds the ingestion *Protective Action Guides* (PAGs).

Derived Response Level (DRL): A Derived Response Level (DRL) relates a *Protection Action Guide* (PAG) to a concentration of radioactive material at which the PAG will be exceeded, using a set of selected assumptions. There are DRLs associated with many PAGs, radioactive materials, exposure pathways, and organs of interest. DRL values may be adjusted during a response to a particular incident when the initial assumptions used to calculate the DRLs are modified to reflect the actual incident conditions. DRLs are typically used when employing the PAGs for ingestion of contaminated foods in order to relate the Food and Drug Administration's *Derived Intervention Levels* (DILs) to specific surface deposition concentrations for a particular radioactive material and ingestion pathway (see *Protective Action Guides: Intermediate Phase PAGs: Ingestion PAGs*).

Effective Dosage (ECt): The cumulative exposure, expressed as the concentration of a chemical or biological material integrated over the time period of exposure (e.g. integrated air concentration – [gram-sec]/m^3) that produces some associated stated effect. This concentration is often associated with a given percentage (XX%) of the population that experiences the stated effect, which is denoted as ECtXX. For example, the effective dosage of a chemical that produces incapacitation in 25% of the exposed population would be expressed as ECt25, or alternatively as ICt25 with an accompanying explanation that the "I" refers to incapacitation. Another typically used notation pertains to effects causing lethality in the population, in which case the ECt is noted as an LCt. If, for example, the ECt is that which causes death in 50% of the exposed population, the ECt is equivalent to the LCt50, where the "L" is assumed to refer to lethal effects.

Effective Dose (ED): This is the quantity of a chemical or biological material that produces some associated stated effect. Unlike *effective dosage*, which is a time-integrated concentration, effective dose is simply expressed as a total amount of material (e.g. spores, grams, etc.). However it is usually associated with a given percentage of the population using similar notation as described above for *effective dosage*. For example, LD30 represents the effective dose of a material that causes lethality in 30% of the exposed population.

Emergency Response Planning Guidelines (ERPGs): One of the three sets of standard

chemical air concentration levels used to estimate the health and safety effects resulting from industrial chemical or chemical warfare agent releases. (*AEGLs* and *TEELs* are the other two sets.) ERPGs are developed by the American Industrial Hygiene Association (AIHA) and are used, if available, for chemical species not having published *AEGLs*. There are up to three ERPG concentrations (labeled as ERPG 1, ERPG 2, and ERPG 3) that reflect increasingly severe health effects with increasing concentration. These guidelines have been developed for exposure periods of up to 1 hour.

Emergency Worker Limits: A set of *dose equivalent* (see *Radiation Dose*) levels, developed the U.S. Environmental Protection Agency (EPA), which should not be exceeded by emergency workers responding to a radiological release (EPA 1992). These levels differ from *Protection Action Guides*, which apply to the general public and are expressed as doses that may be mitigated by specific actions. Emergency Worker Limits are specific projected *Total Effective Dose Equivalent* or *Committed Dose Equivalent* levels due to exposure and intake over the duration of the emergency, and include all doses received while performing lifesaving or protection services.

Ground Shine: Radiation produced by radioactive materials on the surface. Depending on the type and amount of radiation being produced, this may or may not have significant health consequences.

Initial Plots: The first set in a series of plots generated at our computing facility depicting the consequences of a particular atmospheric release of hazardous materials. This set is typically labeled as "SET 1" and is often the result of highly automated processes and can be based on limited information. The dispersion patterns depicted in these initial plots should be treated as preliminary results. Subsequent sets of plots, potentially based on more complete or accurate release information and having been more fully reviewed by our staff, provide refined results.

Interagency Modeling and Atmospheric Analysis Center (IMAAC): An interagency program led by the Department of Homeland Security (DHS) to consolidate and integrate the federal efforts to model the behavior of airborne releases for homeland security events. During an incident of national significance, if required, the IMAAC will be recognized by federal emergency managers as the single source of hazards predictions to be used during the response and recovery phases.

Lethal Dosage (LCt): See *Effective Dosage*.

Lethal Dose (LD): See *Effective Dose*.

National Atmospheric Release Advisory Center (NARAC): The facility, co-located with the Inter-agency Modeling and Atmospheric Assessment Center (IMACC), at Lawrence Livermore National Laboratory (LLNL) that houses the staff and computing resources of the *Atmospheric Release Advisory Capability* (ARAC).

Probit Analysis: A statistical method used to relate the magnitude of some harmful

effect of an incident (e.g. air concentration of a hazardous material, overpressure produced by an explosion, etc.) to the probability that a particular consequence (e.g. death, injury, infection, etc.) will result in the exposed population. Once the relationship between an effect's magnitude and an associated consequence can be estimated by a mathematical expression (see *Probit Slope*), the number or percent of the exposed population expected to experience the consequence can be calculated. This technique is the basis for the fatality and casualty counts, as well as the contours expressed in percentages of the population to experience fatalities, casualties, etc., that appear in our model products (see *Effective Dosage* and *Effective Dose* for related information).

Probit Slope: When using a *probit analysis*, a probit (probability unit) slope specifies the amount of change in the probability of a particular consequence (e.g. death, injury, infection, etc.) resulting from an order of magnitude change in a related effect of a release or incident (e.g. air concentration of a hazardous material, overpressure produced by an explosion, etc.). For example, a chlorine release causes the surrounding chlorine air concentration to increase to harmful levels (an effect of the release) leading to incapacitation in some percentage of the exposed population (a consequence of that effect). When plotting the mathematical relationship that relates the probability of the consequence to order of magnitude changes in the effect, the results are typically described as a straight line. The slope of this line is the probit slope. The probit slope is a function of the effect being modeled (air concentration, explosive overpressure, etc), the material involved (if appropriate), and the resulting consequence of interest (death, injury, etc.). Once the appropriate probit slope is known for a particular effect and its consequence, along with one datum point on the curve expressing the relationship between the two (such as the magnitude of the effect which results in 50% of the affected population to experience the consequence), the magnitude of the effect required to cause any other percentage of the population to experience the consequence may be calculated. Conversely, given the effect strength (e.g. the air concentration of some hazardous material), the percentage of the population that will experience the consequence (e.g. death) may also be calculated. Probit slopes are typically most accurate for the mid-range of the effect magnitudes and consequences of interest, thus there is increased uncertainty for very high (>85%) or very low (<15%) population percentages.

Prompt: Refers to effects that occur over a very short time period, typically seconds to minutes. Primarily used to identify the health and safety consequences resulting from the detonation of a nuclear device, creating immediate overpressure, radiation, and thermal effects. It may also refer to the overpressure effects resulting from the detonation of conventional high explosive.

Protective Action Guides (PAGs): A set of *dose equivalent* (see *Radiation Dose*) levels, developed by the U.S. Environmental Agency (EPA), at which specific protective or mitigating actions should be considered (EPA 1992). These levels reflect the projected, or potential, dose levels that would be delivered to the general population in the absence of protective actions. They apply to any atmospheric release (other than nuclear war) that results in the exposure of the general public to radioactive materials. The PAGs are *dose equivalent* levels at which immediate health effects are unlikely. The

rational for selecting these particular levels is given in EPA 1992, and is principally based on an assessment of the risk to the exposed individuals of developing cancer during their life, or the risk of producing genetic disorders in subsequent generations. There are PAGs that address different phases of the response to a radiological release:

Early Phase PAGs: The early phase of the incident is typically the first few hours or days of the response when immediate decisions must be made to protect the exposed population from radiation produced by the airborne or deposited material. Early phase PAGs are expressed in terms of the projected *TEDE* (see *Radiation Dose*) from exposure over a 4-day period, or in terms of projected *CDE* (see *Radiation Dose*) for those materials that produce a significant thyroid or skin dose. Associated protective actions are evacuation (the urgent short-term removal of the population), sheltering, or (in the presence of airborne radioactive iodines) the administration of stable iodine.

Intermediate Phase PAGs: The intermediate phase of the incident typically covers the time period after the source of the radioactive material has been brought under control through the period when environmental measurements are available for determining the longer-term consequences of the release. This period usually lasts from weeks to months. There are two kinds of intermediate phase PAGs:

Relocation PAG: The projected dose at which relocation (the removal or continued exclusion of the population to avoid chronic radiation exposure) should be considered. Without their relocation, deposition of the radioactive material may continue to produce radiation doses to individuals over extended periods, either directly through *ground shine* or through the inhalation of resuspended radioactive particles (see *Resuspension*). A relocation PAG has been established for projected *TEDE* (see *Radiation Dose*) over the first year. Additional longer-term objectives have been established which limit the projected *TEDE* in any subsequent single year, and over the first 50 years.

Ingestion PAGs: The U.S. Food and Drug Administration (FDA) has developed PAGs based on the projected *CEDE* or *CDE* (see *Radiation Dose*) to specific organs resulting from the ingestion of radioactive materials (FDA 1998). Deposition of radioactive materials onto crops, animal feed, and water can lead to the human ingestion of these materials. There are several potential pathways by which contaminated food may reach the general public. These include direct consumption of contaminated produce (e.g. leafy vegetables) and consumption of animals (e.g. beef) or animal products (e.g. milk) subsequent to the animal's ingestion of contaminated feed. Typically, geographic areas that are expected to exceed a given non-ingestion PAG value are mapped directly in projected dose (e.g in units of rem). However it is usual practice to identify areas that can potentially exceed these ingestion PAGs by mapping the areas where the surface radioactivity levels will cause foods produced in the area to yield ingestion doses that exceed the PAGs. To assist in identifying the limiting levels of surface contamination that correspond to the ingestion PAGs, the FDA has produced *Derived Intervention Levels* (DILs). DILs express the concentration of radioactivity in various foods (vegetables, meats, etc.) that, using assumptions about food consumption, will cause doses exceeding the ingestion PAGs. *Derived Response Levels* (DRLs) have been established which express the radioactivity deposition levels of a particular material (e.g. Plutonium, Cesium,

etc.) that will cause the DIL concentration to be reached in the consumable foods. DRLs are used to map the areas that will eventually lead to ingestion doses in excess of the PAGs. DRLs depend on both the radioactive material of concern as well as the pathway in question (e.g. direct consumption of leafy vegetables, consumption of milk from cows ingesting contaminated feed, etc.) A range of mitigating actions is outlined in FDA 1998. These include providing livestock with protected feed and water, applying a temporary embargo on affected products, and washing to remove surface contamination, as appropriate.

Radiation: Radioactive materials emit energy in the form of photons, charged particles, or neutrons. Radiation is the emission and transport of this energy, and is measured by the amount of emitted energy that is available to be absorbed into a material. Alpha, beta, gamma, and xrays are among the common forms of radiation.

Radioactivity: Radioactivity is a property of materials that undergo nuclear decay, and by doing so emit radiation. It is measured by the rate at which this decay occurs in units of curies or Becquerels (SI unit). The concentration of radioactivity is typically reported per unit area, volume, or mass (e.g. the concentration of a deposited radioactive material may be reported in curies/m^2, while the concentration of radioactive material within food may be expressed in curies/kg).

Radiation Dose: Radioactive materials emit one or more forms of energy (see *Radiation*) that can have harmful effects on the human body. When this energy is absorbed by the body, the degree of injury is determined by the type, amount, and location of the absorbed energy. "Radiation dose" is a general term that can have different, but related, definitions. Radiation dose can refer to the actual quantity of energy (independent of the form) that has been absorbed by some material, such as human tissue. However it can also refer to a quantity that accounts for the amount of biological damage caused by the particular kind of energy being absorbed. The distinction between these meanings is made by using one of the following terms:

Absorbed Dose: This is a quantity of energy that has actually been absorbed into the material. It is independent of the kind of energy and does not reflect the biological effects on the material. Absorbed dose is measured with the unit of rad or gray (SI unit).

Dose Equivalent: Each kind of energy has a different ability to cause biological damage. Therefore equal absorbed doses from two different kinds of energy may produce very different affects on the organs of the human body. A "quality factor" (unique to each kind of energy) is used to convert absorbed doses to a quantity, the dose equivalent, which can be directly compared with other converted absorbed doses (for the same organ), and whose magnitude is proportional to the amount of potential biological damage caused by the absorbed dose. Dose equivalents are measured with the unit of rem or sievert (SI unit), and apply to a specific organ or tissue of the body. There are a few additional terms that can modify this meaning of dose equivalent:

Effective Dose Equivalent (EDE): Dose equivalent to the individual organs can be combined (through the use of organ weighting factors) to calculate the sum of the dose equivalents as applied over the entire body. When this is done the

resulting dose is the Effective Dose Equivalent (EDE).

Committed Dose Equivalent (CDE): Radioactive material that is retained by the body (through inhalation and retention in the lungs, for example) can continue to produce a significant dose over the remainder of the individual's life. Once the material is retained, or committed to the individual, there is little that can be done to avoid the future dose. The Committed Dose Equivalent (CDE) is the dose equivalent that will be delivered to a particular tissue or organ (lung, liver, thyroid, etc.) of the body over the next 50 years after intake of the material.

Committed Effective Dose Equivalent (CEDE): Sum of the CDE to the individual organs and tissues (using the appropriate weighting factors) to calculate a combined dose as applied over the entire body.

Total Effective Dose Equivalent (TEDE): The radioactive material producing the dose equivalent may be external to the body (for example when the material is on the ground or is in the air surrounding the individual), or internal (as when the individual has ingested, or inhaled and retained the material). The Total Effective Dose Equivalent (TEDE) is the sum of the EDE (caused by the external material) and the CEDE (caused by the internal material). The TEDE is the most complete expression of the combined dose from all applicable delivery pathways.

Resuspension: The reintroduction into the atmosphere of material previously deposited onto the surface. One example is a dust plume raised by vehicle traffic through a contaminated area.

Temporary Emergency Exposure Limits (TEELs): One of the three sets of standard chemical air concentration levels used by NARAC staff to estimate the health and safety effects resulting from industrial chemical or chemical warfare agent releases. (*AEGLs* and *ERPGs* are the other two sets.) TEELs are developed by the Subcommittee on Consequence Assessment and Protective Actions (SCAPA), under the U.S. Department of Energy (DOE). Although the AIHA has published *ERPG* values for many chemical species, many chemicals of interest do not currently have associated *ERPGs* (or *AEGLs*). Until *ERPGs* for these chemicals have been reviewed and accepted, a methodology was developed using hierarchies of previously published concentration limit values to develop TEELs (WSRC 1998). TEELs are used, if available, when no *AEGLs* or *ERPGs* have been published for the chemical of interest. There are up to three TEEL concentrations (labeled as TEEL 1, TEEL 2, and TEEL 3) that reflect increasingly severe health effects with increasing concentration.

Acronyms

AEGL	Acute Exposure Guideline Level
AIHA	American Industrial Hygiene Association
ARAC	Atmospheric Release Advisory Capability
CDE	Committed Dose Equivalent (see Radiation Dose)
CEDE	Committed Effective Dose Equivalent (see Radiation Dose)
DIL	Derived Intervention Level
DOE	Department of Energy
DRL	Derived Response Level
ECt	Effective Dosage
ED	Effective Dose
EDE	Effective Dose Equivalent (see Radiation Dose)
EPA	Environmental Protection Agency
ERPG	Emergency Response Planning Guideline
FDA	Food and Drug Administration
IMAAC	Inter-agency Modeling and Atmospheric Assessment Center
LCt	Lethal Dosage
LD	Lethal Dose
LLNL	Lawrence Livermore National Laboratory
NARAC	National Atmospheric Release Advisory Center
NRC	Nuclear Regulatory Commission
PAG	Protective Action Guide
TEDE	Total Effective Dose Equivalent (see Radiation Dose)

TEEL Temporary Emergency Exposure Limit

UTC Coordinated Universal Time

References

EPA 1992, *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents.* Document No. EPA 400-R-92-001, U.S. Environmental Protection Agency, 1992.

FDA 1998, *Accidental Radioactive Contamination of Human Foods and Animal Feeds: Recommendations for State and Local Agencies*. U.S. Food and Drug Administration, August 13, 1998.

WSRC 1998, *Methodology for Deriving Temporary Emergency Exposure Limits (TEELs)*, WSRC-TR-98-00080, Westinghouse Savannah River Company, 1998